SEE Measurements on the Aeroflex MCM Flash Memory

By

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I. Introduction and Overview

This report describes the testing of a Aeroflex Flash Multi Chip Module (MCM) at Texas A&M cyclotron (TAM). This section describes the basics of the test. The description of the TAM test area and facility are contained in section II. Section III contains the test setup and conditions of the test. Section IV contains the results and analyses and the conclusion is in section V.

The purpose of this test was to determine the SEE characteristics of a flash memory under heavy ion radiation. The cross section of each device, for both Single Event Upsets (SEU) and Single Event Latch-up (SEL), as a function of ion Linear Energy Transfer (LET) was the primary goal. The SEU and SEL threshold of these devices was also determined. Another observation was any long term or total dose effects from the ion radiation.

The device parameters are shown in Table 1.

Table 1. The devices tested in this study.

Device	Part Number	Manufacturer	Width	Date Code	Technology
MCM	ACT-F2M32A-090F18C	Aeroflex	16	0044	CMOS/ FAMOS

II. Facility Overview

The SEU test facility at Texas A&M cyclotron is located on the campus of the university. The DOE and the State of Texas jointly support the facility. Institute staff constructed, and now operate, a K500 superconducting cyclotron and its advanced Electron-Cyclotron Resonance (ECR) ion sources. The facility was designed to provide a user friendly and efficient testing station for SEE studies. The ECR Ion Source is highly charged ions for injection into the cyclotron are produced by electron-ion collisions in magnetically confined plasma excited by microwave radiation. These ions are also used for atomic physics experiments on an adjacent high vacuum beamline.

The cyclotron has a dedicated SEE Testing Facility which is designed for advanced radiation testing of Very Large Scale Integrated (VLSI) circuits. This facility features a large-volume target chamber with a versatile target positioning assembly, and a variety of industry standard vacuum feed through connectors. The chambers upstream from the target chamber provide for beam control, diagnostic and dosimetry measurements. A variety of high-energy beams covering a broad range of LET has been developed specifically for this purpose. These beams have a high degree of uniformity over a large cross sectional area. More information can be found at http://cyclotron.tamu.edu/.

The accelerator provides a wide range of ions and energies for SEE testing. Ion species can be changed in approximately 180 minutes while ion energies cannot be changed mid-run. The ions interact with the target in an approximately 10^{-4} torr chamber. The chamber can be depressurized and evacuated in approximately 10 minutes when a device change is desired. The beam can also be run in open air if desired. A list of ions used in this study is shown in Table 2. The most important parameters are the initial LET and range.

Table 2

Particle	Energy(MeV)	InitialLET(Si) (MeV cm2/mg)	Range µm	LETmax (MeV cm2/mg)	Range(LETmax) µm
Ne	546	1.74	799	9.65	790
Ar	1000	5.41	500	20.1	491
Kr	2100	19.2	336	41.4	315
Xe	3200	37.9	286	63.4	254

The interior of the chamber is electrically connected to the test area through an airtight bulkhead. The board on which the Devices Under Test (DUTs) reside is mounted on a moveable stage. The DUT maybe be moved in any of three directions. The DUT may also be rotated. A rectangular iris can changed the diameter of the beam from 0.1 cm to 4 cm in either direction. The beam can be completely positioned from the user console and all positioning information can be saved.

The calculation of the beam LET and range in a desired material is done automatically for each run and saved. Other saved information is the energy, fluence, and time of the run as well as the angle. The system recalculates the LET and adjusts for the fluence when the angle is changed. Hardcopies can be made for redundancy. SEU cross-section curves are generated as the experiment proceeds for easy double monitoring of the experiment.

III. Test Setup and Procedure

The test was comprised of two PCs, a power supply, and a specially designed test board. One PC controlled a HP6629A power supply. This allowed precision voltage control and latch-up detection and protection since the PC had millisecond control over the operation of the power supply, allowing power to be shut down if a high-current situation occurs. Latch-ups are recorded in a separate file.

A dedicated PC controls the test circuit board designed specifically for this test to read and write to the DUTs. This setup allows complete freedom to interact with the DUT. This would allow for any structure in the SEEs or predilection for certain pattern failure or type of SEU to be seen. A depiction of the setup used is shown in Figure 1.

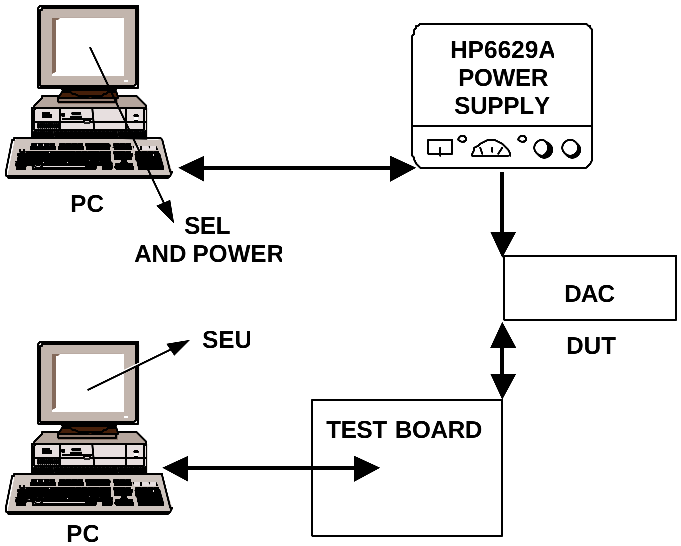

Figure 1. A schematic of the test system.

For this test, the three operational modes were tested: read, write and erase. Standby was also tested. The test of each mode consisted of operating the device in that mode during irradiation and detection the event as a deviation from correct operation.

The Vdd voltage was always set to 5 volts and the operating temp was approximately 40 °C throughout the study.

IV. Results

SEU

Three devices were tested and there was negligible variation between them. All figures are fit by a model given by Edmonds[][1]. Table 3 summarizes the SEL and SEU parameters for this device. Any SEE which occurs in the stand by mode was reset when the device was reinitialized. The results of the test of the read mode of all three DUTs are shown in Figure 3. A read mode error is defined as incorrect data during a read out. There is only one read error type. During readout, upsets occur in the state machine, readout buffer and/or registers. Each upset causes large numbers of errors (up to 10^5 with each upset). Restarting the read function or cycling power read the data out correctly.

[1] Edmonds, L.D. *SEU cross sections derived from a diffusion analysis* Nuclear Science, IEEE Transactions on , Volume: 43 Issue: 6 Part: 2 , Dec. 1996 Page(s): 3207 -3217

No hard errors (actual bit erasures) were seen in 10^{11} particles per square centimeter. Figure 3 plots the cross section of the upsets, not the cross section of errors read.

The results of the test of the write mode of all three DUTs are shown in Figure 4. There was only one kind of write error. The DUT would not be able to write a specific address due to a time out error (inability to write an address in less than one second). This most likely occurs due to state the machine being upset resulting in the changing of the address it was reading for validation from the address that was being written. Power cycle was required on some of the errors to reset the device to normal operation. The cross section of this occurrence is shown in Figure 4.

The results of the test of the erase mode of all three DUTs are shown in Figure 5. Erase errors are similar to write errors since the device is aborted from erasing a part before completion or takes to long to complete. The device is not erased after the occurrence of these errors. Power cycle was required on some of the errors to reset the device to normal operation. Figure 5 shows the cross section of these errors.

SEL

The device showed no Single Event Latchups at any LET. LETs up to 120 MeV-cm^2/mg were tested. Extreme angles and lower energy ions, which should have experienced end of range phenomenon in the sensitive volume of the latchup, did not trigger latch-up.

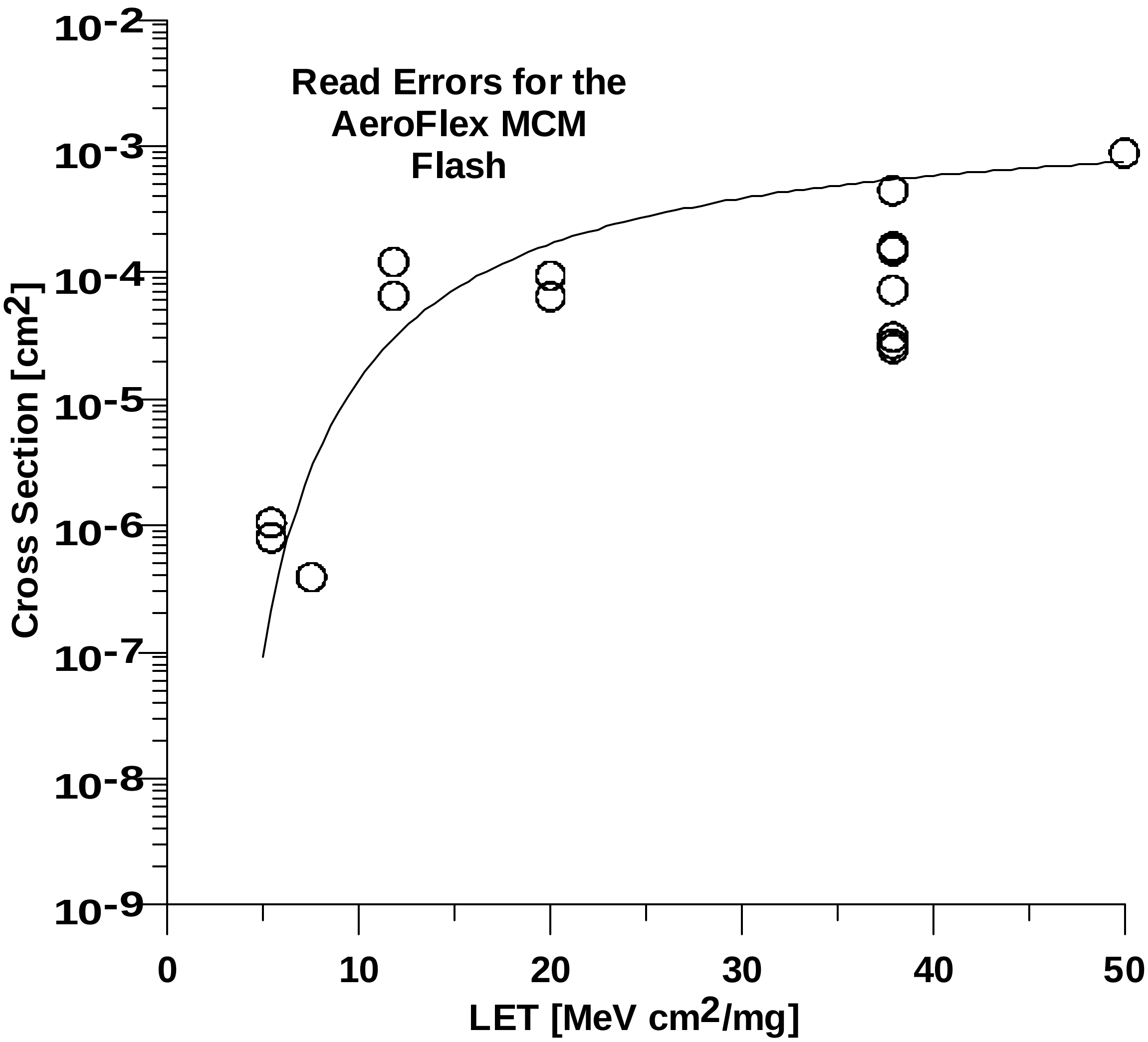

Figure 2. Cross-section of the whole device as a function of LET. Read errors are upsets in the output through the buffers and control logic. Re-initializing readout clears these errors. These errors are not to the memory bits, no errors to the actual non-volatile memory cells were observed.

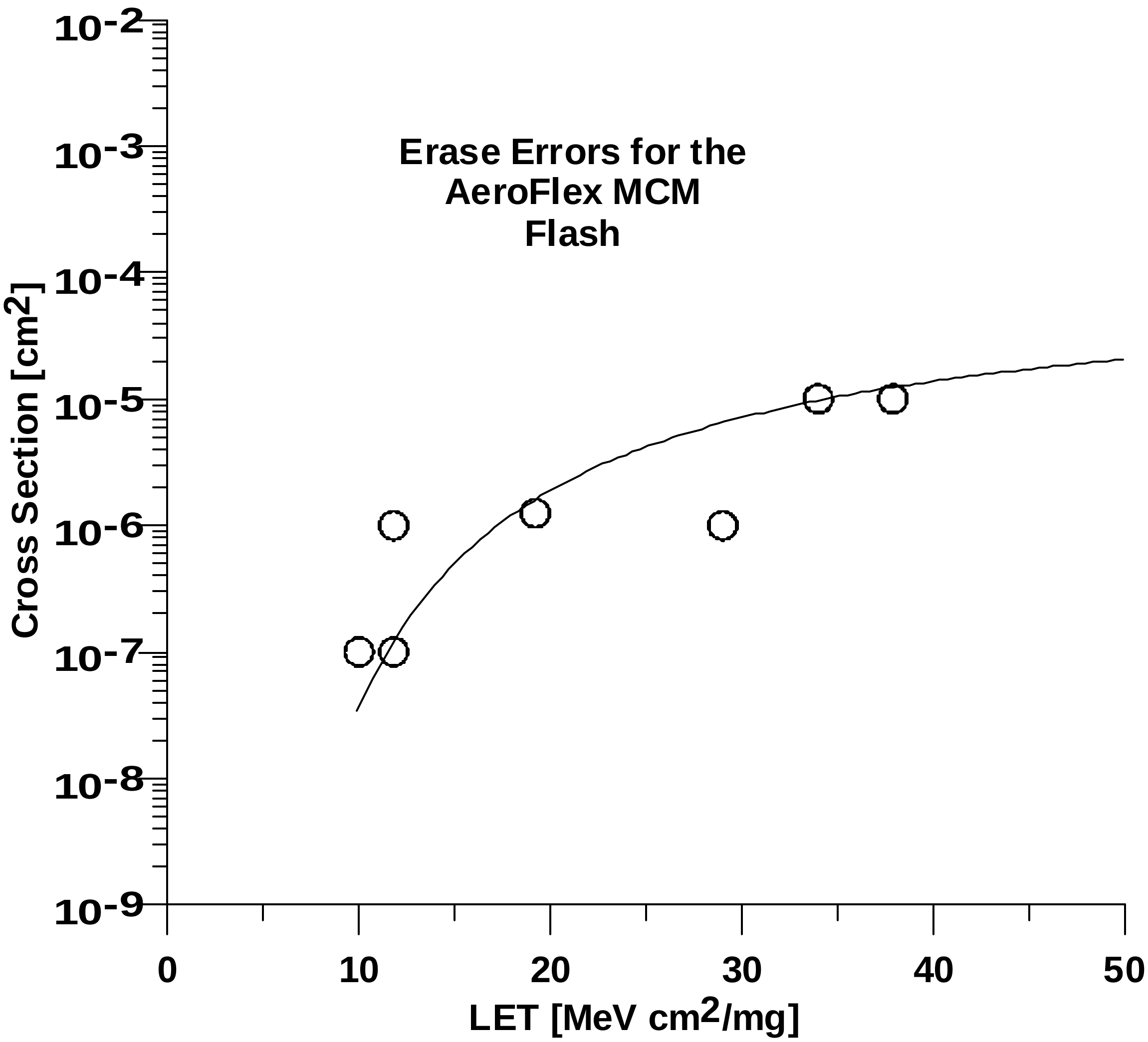

Figure 3. Cross-section of the whole device as a function of LET. Erase errors are the inability of the device to erase the directed number of cells during irradiation. Power cycle was required on some of the errors to reset the device to normal operation.

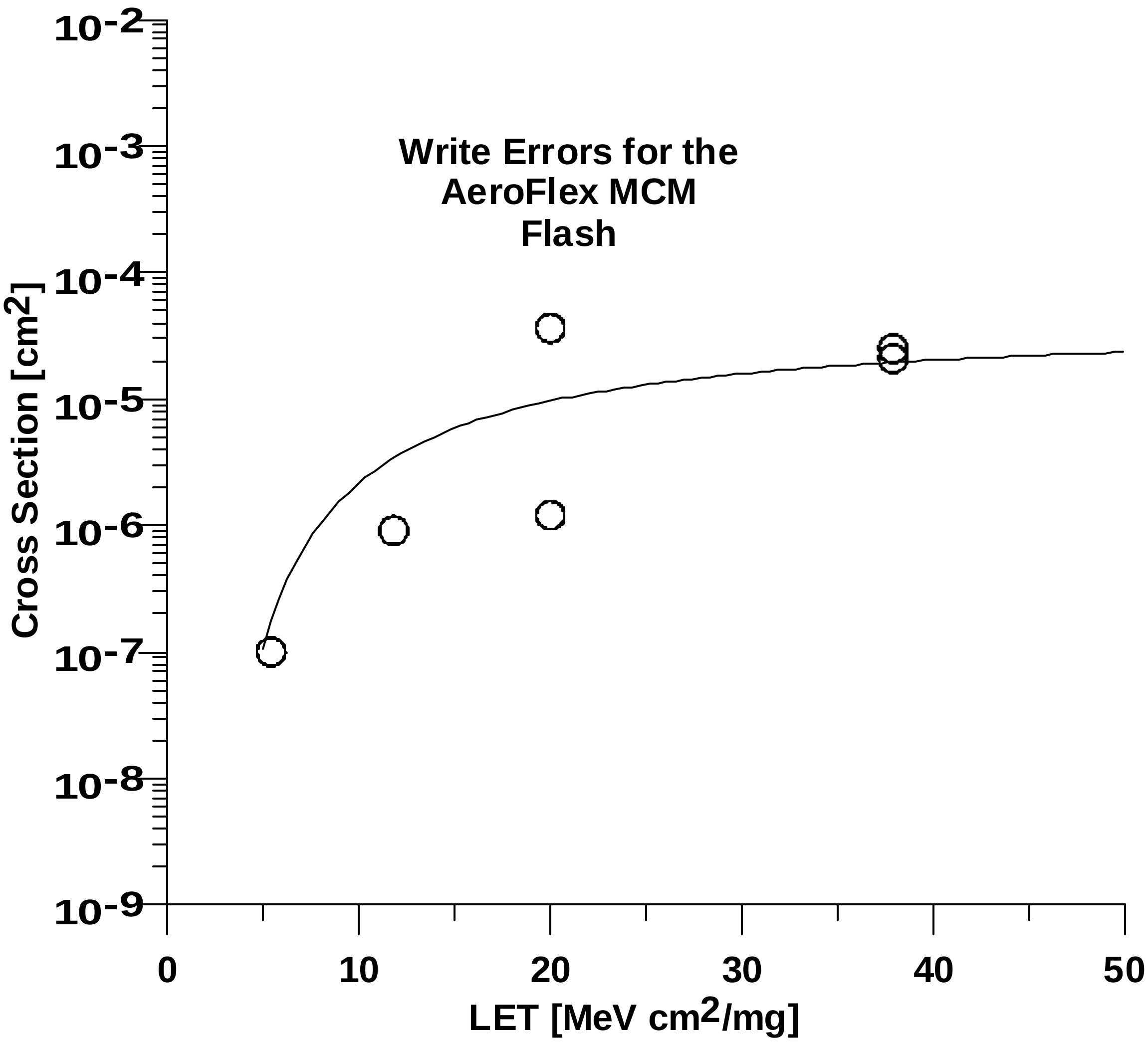

Figure 4. Cross-section of the whole device as a function of LET. Write errors are the inability of the device to write a cell and verify the write. Power cycle was required on some of the errors to reset the device to normal operation.

V. Conclusion

These devices are apparently SEL-immune. These devices are very sensitive to single event upset during any operation mode. These are most likely due to errors in the control logic. Errors that occur in standby mode are not seen, as the device should reset them when a new operation is initialized. The results of the testing are shown in Table 3.

Table 3.

Device	Mode	SEL Threshold [MeV-cm^2/mg]	SEU Threshold [MeV-cm^2/mg]	SEU Saturation Device Cross-section [cm^2]	Require power cycle to recover from error?
MCM Flash	Read	>120	5	1e-3	No
MCM Flash	Erase	>120	7	5e-5	Sometimes
MCM Flash	Write	>120	5	2e-5	Sometimes